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# (54) System for injecting nitrogen oxide reducer into an exhaust gas flow

(57) A system for injecting a nitrogen oxide reducer into an exhaust gas flow, in particular for a combustion engine, has a injection element for controlled injection of the reducer into the exhaust gas flow.

The injection element contains a micromechanical nozzle element 1a, 1b which injects the reducer controllably into the exhaust gas flow through a multiplicity of fine nozzle openings 10 in the form of fine jets by means of local, measured generation of overpressure. This pressure is obtained by energising heating elements in the nozzle so that the liquid instantly vaporises, or by use of piezo-electrically driven diaphragms.

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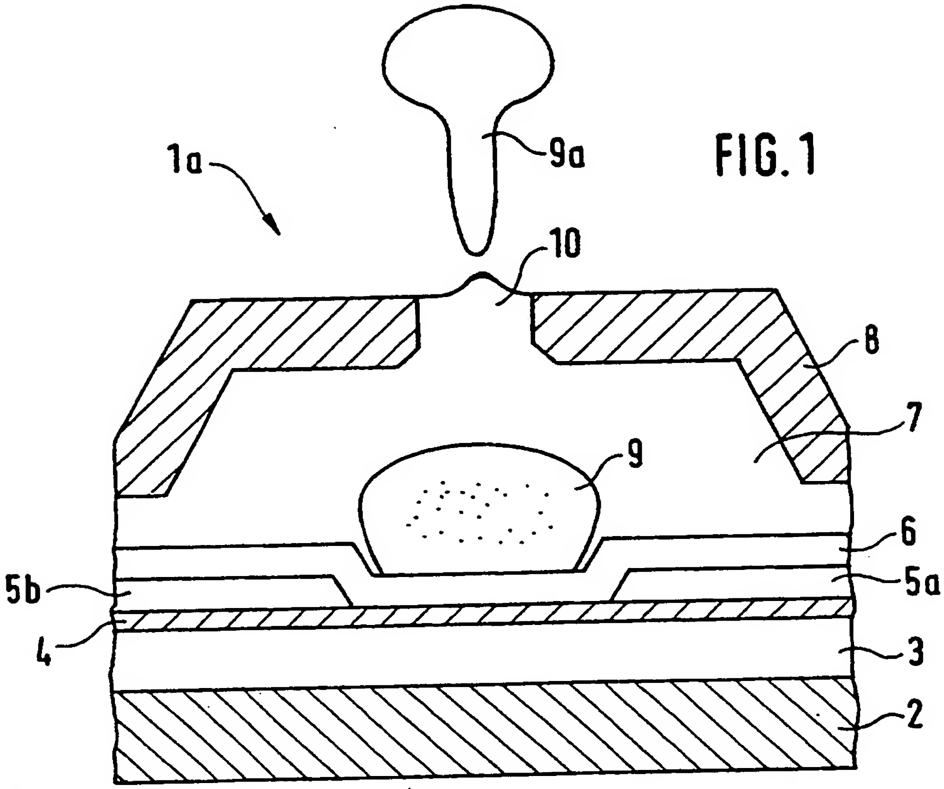


FIG. 1

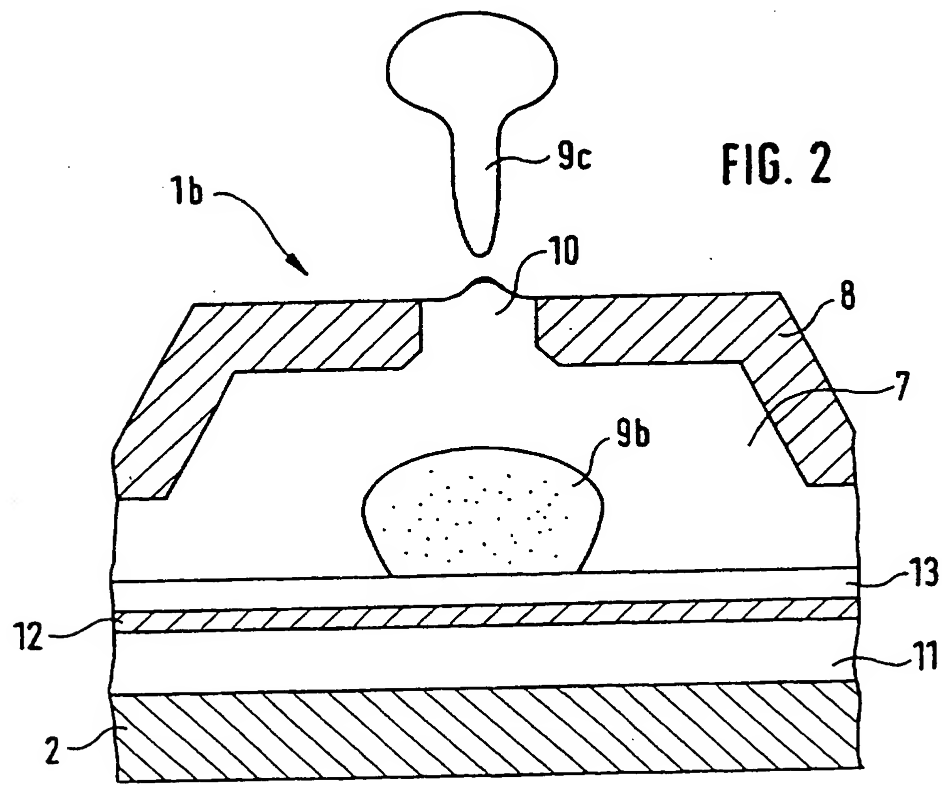


FIG. 2

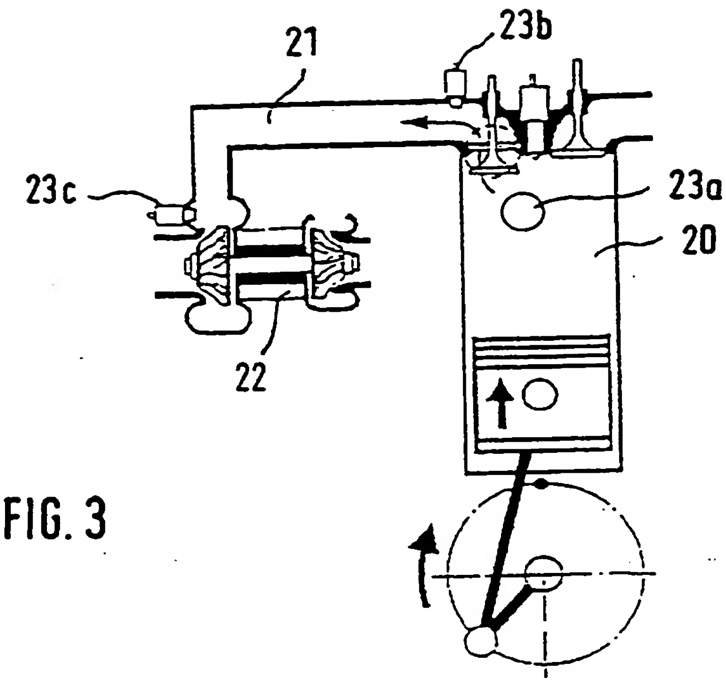


FIG. 3

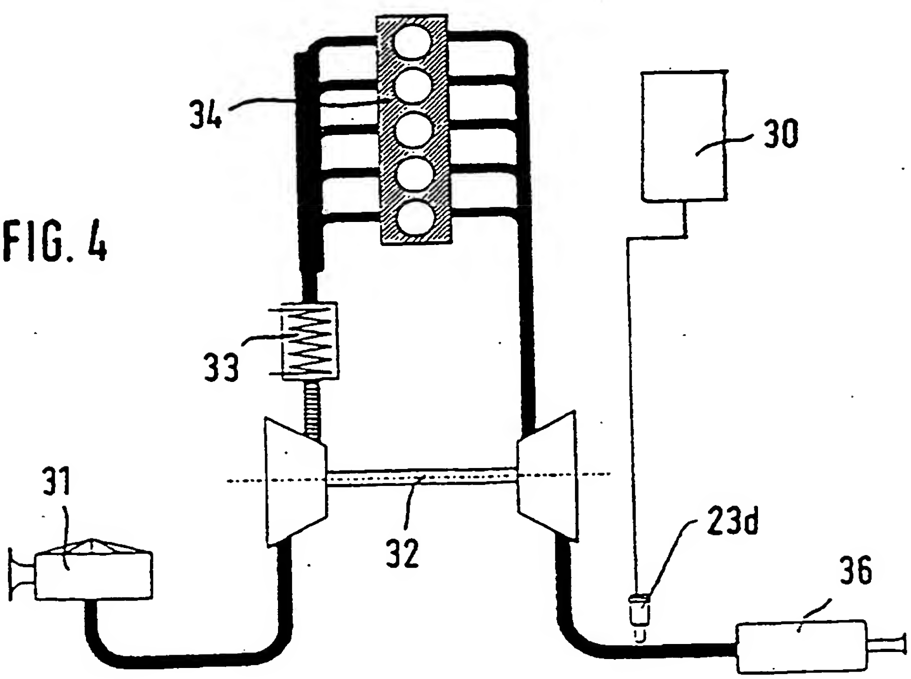


FIG. 4

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# System for injecting nitrogen oxide reducer into an exhaust gas flow

The invention relates to a system for injecting a nitrogen oxide reducer into an exhaust gas flow, in particular but not exclusively for an internal combustion engine, having an injection element for controlled injection of the reducer into the exhaust gas flow.

Catalytic reduction of the emitted nitrogen oxides without additional reducer is not possible in the case of combustion processes with excess air. A remedy known from power station engineering is a so-called selective catalytic reduction in which a reducer, for example ammonia or water-dissolved urea, is injected into the exhaust gas flow upstream of a catalytic converter. The injected ammonia or the ammonia released during pyrolysis of urea reduces the nitrogen oxide in the catalytic converter to molecular nitrogen and water. Consequently, selective catalytic nitrogen oxide reduction has also already been proposed for combustion engines, in which case an appropriate reducer is injected, using conventional injection technology, into the combustion chamber or the adjoining exhaust gas section upstream of an exhaust gas catalytic converter. In addition, it is possible to create in the exhaust gas flow of a combustion engine chemical and physical relationships which permit the nitrogen oxides contained therein to be reduced even without a catalytic converter. This method is termed selective non-catalytic reduction and after the conventional injection of the reducer it firstly requires the latter to be vaporized, and this increases the required residence time. It is therefore primarily suitable for low-speed engines.

A system for injecting ammonia into the exhaust gas flow of a diesel engine is disclosed in Laid-Open Specification EP 0 381 236 A1. Provision is made there of an overpressure reservoir for the ammonia used as reducer, and of an associated transport line and of a conventional injection nozzle, arranged upstream of a catalytic converter, for injecting said ammonia into the exhaust gas flow. Sensors are used to determine the humidity and temperature of the intake air, the fuel consumption, the output and the exhaust gas temperature of the diesel engine. A control unit uses a control valve to control the quantity of ammonia injected into the exhaust gas flow, as a function of these input values.

Patent Specification DE 38 21 832 C1 describes an exhaust gas system for a piston combustion engine with an exhaust gas turbocharger, which is set up for selective, non-catalytic nitrogen oxide reduction. Arranged upstream of the exhaust gas turbocharger at a junction of various branches of the exhaust gas system is an injection element which contains a multiplicity of nozzle openings. A feed pump is used to introduce ammonia under pressure via an atomizer nozzle into a mixing chamber connected upstream of the nozzle openings, and to mix it there with a carrier gas. The ammonia/carrier gas mixture is then injected under pressure into the exhaust gas flow through the nozzle openings, the pressure being generated by compressors which feed the carrier gas and compressed air. The nozzle can be arranged in an axially displaceable fashion inside the region of the junction.

Laid-Open Specification JP 3-206314 (A) discloses an injection device which serves to inject gaseous ammonia into the exhaust gas flow of a diesel engine and is arranged upstream of an exhaust gas catalytic converter. With the aid of a gas pressure reservoir, a storage tank feeds aqueous ammonia solution to heating tubes which lead transversely into an exhaust pipe and open into an evaporation/expansion chamber. The evaporation/expansion chamber situated in the exhaust pipe is fed vaporized ammonia solution from the heating tubes. The heated and gaseous ammonia passes from the evaporation/expansion chamber into the exhaust gas flow through a porous nozzle.

A conventional atomizer nozzle which can be used to inject a reactant, for example urea, into an exhaust gas flow is described in Laid-Open Specification EP 0 586 913 A2. Pressurized gas and a liquid reactant are fed to a mixing chamber situated outside the atomizer nozzle. The reactant/gas mixture produced in the mixing chamber passes via a mixing pipe into a nozzle antechamber, provided with a filter, of the atomizer nozzle. The mixture is accelerated by an intermediate nozzle and passes into the main chamber of the atomizer nozzle, in which further mixing is performed. From the main chamber, the reactant/gas mixture enters the exhaust gas flow upstream of a catalytic converter via nozzle openings.

Micromechanical nozzle elements which have a multiplicity of fine nozzle openings through which a fed fluid is brought out in the form of fine jets by means of clocked generation of overpressure limited locally to the regions of the nozzle openings are used, for example, in ink-jet printers. Electric heating resistors are used for the

purpose of generating overpressure locally in so-called bubble-jet printers, and piezoelectrically actuated diaphragms are used in the case of piezo-jet printers. The micromechanical nozzle element is used to inject printing ink onto a paper, a fine distribution and thus a high spatial resolution being achieved by the very small nozzle openings. Ink-jet printer nozzles of these designs are described, for example, in Laid-Open Specifications DE 30 12 936 A1 and DE 195 31 740 A1.

The present invention seeks to provide a system of the type mentioned at the beginning by means of which the reducer can be introduced into the exhaust gas flow with a relatively low outlay accompanied by comparatively good mixing.

According to one aspect of the present invention there is provided a system for injecting a nitrogen oxide reducer into an exhaust gas flow, having

- an injection element for controlled injection of the reducer into the exhaust gas flow, which injection element contains a micromechanical nozzle element which injects the reducer controllably into the exhaust gas flow through a multiplicity of fine nozzle openings in the form of fine jets by means of local, clocked generation of overpressure, means for the local generation of overpressure, comprising heating resistor elements which are arranged in the region of the respective nozzle openings and by means of which the reducer fed in liquid form is locally heated and thereby injected into the exhaust gas flow in the form of fine vapour jets, and
- a reducer injection control unit which controls the injection instant and/or the injection quantity of the reducer in the exhaust gas flow, at least as a function of operating parameters.

According to a second aspect of the present invention there is provided a system for injecting a nitrogen oxide reducer into an exhaust gas flow, having

- an injection element for controlled injection of the reducer into the exhaust gas flow, which contains a micromechanical nozzle element which injects the reducer controllably into the exhaust gas flow through a multiplicity of fine nozzle openings in the form of fine jets by means of local, clocked generation of overpressure, means for the local generation of overpressure, comprising piezoelectrically actuated diaphragms which are arranged in the region of the respective nozzle openings, and
- a reducer injection control unit which controls the injection instant and/or the injection quantity of the reducer into the exhaust gas flow, at least as a function of operating

parameters.

In these systems, the nitrogen oxide reducer is injected into the exhaust gas flow, for example of a combustion engine, via a controllable injection element which contains a micromechanical nozzle element which, for example, employs technology used in ink-jet printers and injects the reducer into the exhaust gas flow, in a controllable fashion with good mixing, through a multiplicity of fine nozzle openings in the form of fine jets by means of local, clocked generation of overpressure. The use of micromechanical nozzle elements with local generation of overpressure limited to the regions of the nozzle openings permits a simple design of the system without pressurized pipes and separate pressure pumps. A reducer injection control unit controls the injection instant and/or the injection quantity of the reducer into the exhaust gas flow of a combustion engine, at least as a function of engine speed, engine load, crank angle and/or exhaust gas temperature. Good nitrogen oxide reduction is achieved in the exhaust gas flow using this injection, which is a function of operating parameters, and over-dosing of the reducer is avoided at the same time.

In the system according to the first aspect, as means for the local generation of overpressure provision is specifically made of heating resistor elements which are arranged in the region of the respective nozzle openings and by means of which the reducer fed in liquid form is locally superheated and thereby injected into the exhaust gas flow in the form of fine vapour jets. Owing to injection in the vaporized state, positive preliminary reactions for the later reduction of nitrogen oxides can be already initiated during the injection process, and the mixing of reducer with the exhaust gas flow is facilitated.

In the case of the system according to the second aspect, the means for local generation of overpressure are specifically constructed as piezoelectrically actuated diaphragms arranged in the region of the respective nozzle openings. The use of such a piezoelectrically operated nozzle element permits particularly accurate dosing of the injected reducer.

In accordance with a development of the invention, the nozzle openings are arranged distributed over a large area along the path of the exhaust gas stream. The reducer can thereby be introduced into the exhaust gas flow with a relatively low outlay accompanied by comparatively good mixing and distribution.

In a preferred embodiment of the invention, for the purpose of selective, non-catalytic nitrogen oxide reduction in a combustion engine, the nozzle openings in the combustion chamber and/or in the outlet channel and/or, immediately upstream of the exhaust gas turbine of an exhaust gas turbocharger, open into the path of the exhaust gas stream of, and the injection control unit causes the injection of reducer only if the exhaust gas temperature is higher than a predetermined minimum temperature. The latter is selected in such a way that the injection of reducer is avoided if the exhaust gas temperature is insufficient to reduce nitrogen oxide.

In a further development of the invention, for the purpose of selective catalytic nitrogen oxide reduction by means of an exhaust gas catalytic converter located in the path of the exhaust gas stream, the nozzle openings open into the path of the exhaust gas stream upstream of the catalytic converter, and the control unit causes the injection of reducer only if the exhaust gas temperature is higher than the predetermined minimum temperature for catalytic converter activity. The latter is selected in such a way that the injection of reducer is avoided in the case of a catalytic converter which is not operating because of the temperature.

Preferred exemplary embodiments of the invention are represented in the drawings and described below. In the drawings:

Fig. 1 shows a partial sectional view of a micromechanical nozzle element having heating resistor elements as a part of an injection element of a system for injecting a nitrogen oxide reducer into the exhaust gas flow of a combustion engine,

Fig. 2 shows a partial sectional view of a micromechanical nozzle element having piezoelectrically controllable diaphragms as part of an injection element of a system for injecting a nitrogen oxide reducer into the exhaust gas flow of a combustion engine,

Fig. 3 shows a diagrammatic representation of a piston engine having a system for injecting a nitrogen oxide reducer into the exhaust gas flow for the purpose of selective non-catalytic nitrogen oxide reduction, and

Fig. 4 shows a diagrammatic representation of a piston engine having a system for injecting a nitrogen oxide reducer into the exhaust gas flow for the purpose of selective catalytic nitrogen oxide reduction.

The micromechanical nozzle element 1a, partially represented in Fig. 1, for injecting a nitrogen oxide reducer into the exhaust gas flow of a combustion engine contains a substrate 2 on which there is arranged a thermal barrier 3 to which, in turn, there is applied an electric resistance layer 4 with which contact is made via supply leads 5a, 5b. Arranged on the supply leads 5a, 5b and the resistance layer 4 is an insulating and passivating layer 6 which serves the purpose of electrical insulation and protection against chemically aggressive reducers. Adjoining above the insulating and passivating layer 6 is a nozzle chamber 7 to which a liquid nitrogen oxide reducer is fed, and which is bounded above by a nozzle plate 8. A multiplicity of micromechanically fine nozzle openings 10, of which one is to be seen in Fig. 1, are introduced into the nozzle plate 8. The supply leads 5a, 5b are interrupted in the region below each nozzle opening 10, with the result that the insulating and passivating layer 6 rests here directly on the resistance layer 4. This design corresponds to the bubble-jet technology of ink jet printer nozzles.

If the resistance layer 4 is fed electric energy via the supply leads 5a, 5b, the middle region of said layer, which serves as a heating resistor element below the respective nozzle opening 10, is heated suddenly and the reducer, which is separated therefrom in this region only by the insulating and passivating layer 6, is superheated there locally. This results in an explosive, local vaporization of the reducer and a corresponding local overpressure, which is indicated diagrammatically in Fig. 1 by an illustrated vapour bubble 9. As a result, the reducer emerges from the nozzle openings 10 in the form of fine vapour jets, and is thus injected into the exhaust gas flow in a finely distributed fashion and well mixed. A reducer vapour bubble 9a which has just emerged is indicated in Fig. 1 diagrammatically above the nozzle opening 10. If the supply of current to the resistance layer 4 is interrupted, the latter cools down and no further reducer emerges from the nozzle openings 10. The vaporization of the reducer before injection into the exhaust gas flow already produces thermal preparation in the injection element. It is possible as a result to initiate preliminary reactions of the respective reducer which are positive for the later nitrogen oxide reduction: examples are the thermal pyrolysis of urea or the thermal cracking of diesel fuel to form hydrocarbon radicals.

Fig. 2 shows a further micromechanical nozzle element 1b, the

components with the same function as in the example of Fig. 1 being provided with the same reference numerals. Arranged on a substrate 2 is an intermediate layer 11 on which a piezoelectric element 12 is constructed in the form of a layer. Contact is made in a suitable way with the piezoelectric element 12 via supply leads (not shown). Applied to the piezoelectric element 12 is a diaphragm 13 which separates the piezoelectric element from the liquid reducer, which is located above the diaphragm 13 in the nozzle chamber 7. The nozzle chamber 7 is bounded above by the nozzle plate 8, with the fine nozzle openings 10 which are located therein. The application of a suitable electric field via the supply leads (not shown) to the piezoelectric element 12 locally causes a deflection of the same in the region below the respective nozzle opening 10, and thus deflects the diaphragm 13 upwards. A local overpressure is consequently produced in the nozzle chamber 7, as a result of which reducer emerges from the respective nozzle opening 10 in the form of a fine jet of microscopic droplets 9b, 9c. Very exact dosing of the quantity of reducer emerging through the nozzle openings 10 is possible due to the piezoelectric actuation of the diaphragm 13. This principle corresponds to the piezo-jet technology of ink jet printer nozzles.

The two exemplary embodiments of Fig. 1 and Fig. 2 have in common that the overpressure required for the injection is produced locally directly in the respective nozzle opening region, and that therefore no pressurized pipes or separate overpressure pumps are needed. Because of the small dimensions of the nozzle openings and the large number of nozzle openings, which are preferably arranged over a large area along the path of the exhaust gas stream, there is good mixing and a comparatively homogeneous and fine distribution of the reducer in the exhaust gas flow.

Fig. 3 shows a diagrammatic representation of a piston engine having a system for injecting a nitrogen oxide reducer into the exhaust gas flow for the purpose of selective non-catalytic nitrogen oxide reduction. The piston engine can be, for example, a quality-controlled diesel engine which is operated with air excess, or a spark-ignition engine with lean operation, that is to say with an air/fuel ratio leaner than stoichiometric. An exhaust duct 21 with an exhaust gas turbocharger 22 adjoins a combustion chamber 20. The reducer injection system contains three injection elements 23a, 23b and 23c, which are arranged at different points along the path of the exhaust gas stream.

The first injection element 23a is arranged in the combustion chamber of the piston engine and only indicated in Fig. 3. The second injection element 23b is arranged in the exhaust duct 21 on the cylinder head, whereas the third injection element 23c is fitted directly upstream of the exhaust gas turbine of the exhaust gas turbocharger 22. Prevailing at these positions are temperature and turbulence boundary conditions which favour effective non-catalytic nitrogen oxide reduction using the injected reducer. Each injection element contains a micromechanical nozzle element of one of the designs described in Figs. 1 and 2, with the result that micromechanically fine nozzle openings are arranged distributed over a large area at each of the three injection points. The overall result of this is a large-area distribution of the nozzle openings along the path of the exhaust gas stream, and this in turn permits good mixing of the reducer with the exhaust gas, and therefore effective non-catalytic nitrogen oxide reduction. It goes without saying that it is possible as an alternative to arrange a respective injection element at only one or two of the three points shown.

The injection elements 23a, 23b, 23c are fed with reducer by conventional devices (not shown). The control of the injection elements is performed by a control unit (not shown). The control unit causes injection of reducer into the exhaust gas flow only if the exhaust gas temperature in the cylinder of the piston engine is higher than the predetermined temperature which is required for non-catalytic reduction of nitrogen oxide with the reducer used. This avoids, in particular, secondary pollution of the exhaust gas by nonreacting reducer. In principle, the production of pressure in the injection elements 23a, 23b, 23c is limited to the injection periods. In addition, there is no need for any pressurized pipes with the appropriate seals.

Fig. 4 shows a further piston engine, which is provided with a system for selective catalytic nitrogen oxide reduction. This piston engine can also be, for example, a quality-controlled diesel engine which is with air excess, or a spark-ignition engine operation with lean operation. Intake air passes via an air filter and intake air silencer 31 to the compressor of an exhaust gas turbocharger 32. The compressed air is led via a charge air cooler 33 and passes into the combustion chamber 34 of the piston engine. The exhaust gases of the piston engine drive the exhaust gas turbine of the exhaust gas turbocharger 32. Arranged downstream of the exhaust gas turbine and upstream of an exhaust gas catalytic converter 36 is an injection element 23d which includes a

micromechanical nozzle element in accordance with Figs. 1 or 2, for injecting reducer into the exhaust gas flow. The fine nozzle openings of the injection element 23d are arranged in this case distributed over a large area upstream of the exhaust gas catalytic converter 36, and permit good mixing of the injected reducer in conjunction with a comparatively simple design of the injection element 23d.

A control unit 30 controls the injection instant and injection quantity of the reducer as a function of engine speed, engine load, crank angle and exhaust gas temperature. These parameters are detected by sensors (not represented). The injection can therefore be performed in a fashion tuned to the prevailing engine operating conditions, thus permitting a substantial reduction in the nitrogen oxide of the exhaust gas. In the present case of selective catalytic nitrogen oxide reduction, the exhaust gas temperature is measured in the region upstream of the catalytic converter 36, and the control unit 30 causes reducer to be injected only if the exhaust gas temperature is higher than a predetermined minimum temperature for catalytic converter activity. It follows that no reducer passes into the exhaust gas flow as long as the catalytic converter is still not able to function because of an excessively low operating temperature.

Claims

1. A system for injecting a nitrogen oxide reducer into an exhaust gas flow, having

- an injection element for controlled injection of the reducer into the exhaust gas flow, which injection element contains a micromechanical nozzle element which injects the reducer controllably into the exhaust gas flow through a multiplicity of fine nozzle openings in the form of fine jets by means of local, clocked generation of overpressure, means for the local generation of overpressure, comprising heating resistor elements which are arranged in the region of the respective nozzle openings and by means of which the reducer fed in liquid form is locally heated and thereby injected into the exhaust gas flow in the form of fine vapour jets, and
- a reducer injection control unit which controls the injection instant and/or the injection quantity of the reducer in the exhaust gas flow, at least as a function of operating parameters.

2. A system for injecting a nitrogen oxide reducer into an exhaust gas flow, having

- an injection element for controlled injection of the reducer into the exhaust gas flow, which contains a micromechanical nozzle element which injects the reducer controllably into the exhaust gas flow through a multiplicity of fine nozzle openings in the form of fine jets by means of local, clocked generation of overpressure, means for the local generation of overpressure, comprising piezoelectrically actuated diaphragms which are arranged in the region of the respective nozzle openings, and
- a reducer injection control unit which controls the injection instant and/or the injection quantity of the reducer into the exhaust gas flow, at least as a function of operating parameters.

3. A system according to Claim 1 or 2, wherein the nozzle openings are distributed over a large area along the path of the exhaust gas stream.

4. A system according to any one of Claims 1 to 3, adapted for use with an

internal combustion engine, wherein

- the nozzle openings open into the combustion chamber and/or into the outlet channel and/or, immediately upstream of the exhaust gas turbine of an exhaust gas turbocharger, into the path of the exhaust gas stream of the combustion engine, and
- the injection control unit causes the injection of reducer only if the exhaust gas temperature is higher than the minimum temperature required for non-catalytic nitrogen oxide reduction.

5. A system according to any one of Claims 1 to 3, wherein

- the nozzle openings open into the path of the exhaust gas stream upstream of an exhaust gas catalytic converter of a combustion engine, and
- the injection control unit causes the injection of reducer only if the exhaust gas temperature is higher than a predetermined minimum temperature for catalytic converter activity.

6. A system according to any one of claims 1 to 5, adapted for use with an internal combustion engine wherein the said parameters comprise at least the engine speed, engine load, crank angle and/or exhaust gas temperature.

7. A system for injecting a nitrogen oxide reducer into an exhaust gas flow, substantially as described herein with reference to, and as illustrated in, the accompanying drawings.

Amendments to the claims have been filed as follows

## Claims

1. A system for injecting a nitrogen oxide reducer into an exhaust gas flow, having
- an injection element for controlled injection of the reducer into the exhaust gas flow, which injection element contains a micromechanical nozzle element which injects the reducer controllably into the exhaust gas flow through a multiplicity of fine nozzle openings in the form of fine jets, by local generation of overpressure produced by means comprising heating resistor elements which are arranged in the region of the respective nozzle openings and by means of which the reducer fed in liquid form is locally heated and thereby injected into the exhaust gas flow in the form of fine vapour jets, and
- a reducer injection control unit which controls the injection instant and/or the injection quantity of the reducer in the exhaust gas flow, at least as a function of operating parameters.

2. A system for injecting a nitrogen oxide reducer into an exhaust gas flow, having
- an injection element for controlled injection of the reducer into the exhaust gas flow, which contains a micromechanical nozzle element which injects the reducer controllably into the exhaust gas flow through a multiplicity of fine nozzle openings in the form of fine jets, by local generation of overpressure produced by means comprising piezoelectrically actuated diaphragms which are arranged in the region of the respective nozzle openings, and
- a reducer injection control unit which controls the injection instant and/or the injection quantity of the reducer into the exhaust gas flow, at least as a function of operating parameters.

3. A system according to Claim 1 or 2, wherein the nozzle openings are distributed over a large area along the path of the exhaust gas stream.

4. A system according to any one of Claims 1 to 3, adapted for use with an

internal combustion engine, wherein

- the nozzle openings open into the combustion chamber and/or into the outlet channel and/or, immediately upstream of the exhaust gas turbine of an exhaust gas turbocharger, into the path of the exhaust gas stream of the combustion engine, and
- the injection control unit causes the injection of reducer only if the exhaust gas temperature is higher than the minimum temperature required for non-catalytic nitrogen oxide reduction.

5. A system according to any one of Claims 1 to 3, wherein

- the nozzle openings open into the path of the exhaust gas stream upstream of an exhaust gas catalytic converter of a combustion engine, and
- the injection control unit causes the injection of reducer only if the exhaust gas temperature is higher than a predetermined minimum temperature for catalytic converter activity.

6. A system according to any one of claims 1 to 5, adapted for use with an internal combustion engine wherein the said parameters comprise at least the engine speed, engine load, crank angle and/or exhaust gas temperature.

7. A system for injecting a nitrogen oxide reducer into an exhaust gas flow, substantially as described herein with reference to, and as illustrated in, the accompanying drawings.

The Patent Office

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**Claims searched:** 1-7

**Examiner:** John Warren
**Date of search:** 25 February 1998

# Patents Act 1977
# Search Report under Section 17

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK-Cl (Ed.P): B1W

Int Cl (Ed.6): B01D 53/56, 53/86, 53/94; B05B 7/32; F01N 3/20

Other: ONLINE Databases: WPI and CLAIMS

**Documents considered to be relevant:**

| Category | Identity of document and relevant passage | Relevant to claims |
|---|---|---|
| | NONE | |

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|---|---|---|---|
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